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MEASUREMENT ERROR OF POLICE DATA TO IDENTIFY SOLID WASTE DUMPING SITES

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ABSTRACT

The increasing number of illegal dumping sites in rural regions of Spain represents a worrying problem in terms of sustainable construction and demolition (C&D) waste management. Local and regional authorities should have an effective system to control this issue. In fact, the Nature Protection Service of the Civil Guard (known as SEPRONA) has data on administrative sanctions of illegal dumping. However, the lack of reliable official data increases the uncertainty and control of rubble. This study analyzes the administrative sanctions for C&D waste that took place in Extremadura (Spain) in 2018. A total of 1 238 geolocations about illegal dumping provided by SEPRONA were analyzed. The main objective was to analyze the reliability of police data to locate solid spills in Extremadura. A detailed verification of the presence of rubble was conducted through interviews with the Civil Guard agents, field survey and photo-interpretation using up-to-date orthophotographs. The main findings showed a low quality in the georeferencing of the complaints. Only 2 % were clearly located in sites where C&D waste could be observed, and 9 % of the complaint is not exactly located in places where waste can be observed, but this kind of rubble was observed in close proximity to the geolocation. There is a lack of police culture to take advantage of GIS data for crime studies, and field agents do not use accurate techniques for georeferencing. Therefore, a good training for field agents and the development of a good practice guide can be key to ameliorate this problem.

Keywords: Illegal dumping; construction and demolition (C&D) waste; police data; georeferencing error.

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ERROR DE MEDICIÓN DE DATOS POLICIALES PARA IDENTIFICAR VERTEDEROS

RESUMEN

El creciente número de vertederos ilegales en las regiones rurales de España representa un problema preocupante en términos de gestión sostenible de los residuos por construcción y demolición (RCD). Las autoridades locales y regionales deben tener un sistema eficaz para controlar este problema. De hecho, el Servicio de Protección de la Naturaleza de la Guardia Civil (conocido como SEPRONA) dispone de datos sobre sanciones administrativas por vertederos ilegales. Sin embargo, la falta de datos oficiales fiables aumenta la incertidumbre y el control de los escombros. Este estudio analiza las sanciones administrativas por RCD que tuvieron lugar en Extremadura (España) en 2018. Se analizaron un total de 1 238 geolocalizaciones sobre vertederos ilegales proporcionadas por el SEPRONA. El objetivo principal fue analizar la fiabilidad de los datos policiales para localizar vertederos en Extremadura. Se realizó una verificación detallada de la presencia de escombros mediante entrevistas a los agentes de la Guardia Civil, trabajo de campo y fotointerpretación con ortofotografías actualizadas. Los principales hallazgos mostraron una baja calidad en la georreferenciación de las denuncias. Solo el 2 % estaban claramente ubicadas en sitios donde se observaban RCD, y el 9 % de las denuncias no se ubicaron exactamente en lugares donde se podían observar residuos, pero muy cerca de la geolocalización. Existe una falta de cultura policial para aprovechar los datos SIG en estudios delictivos y una ausencia de manejo de técnicas precisas de georreferenciación por parte de los agentes. Por tanto, una buena formación de los agentes policiales y la elaboración de una guía de buenas prácticas pueden ser claves para paliar este problema.

Palabras clave: vertidos ilegales; residuos de construcción y demolición (C&D); datos policiales; error de georreferenciación.

1. Introduction

Illegal dumping of construction and demolition (C&D) waste is a worldwide problem that negatively affects the environment and social life of communities. In Spain it is very common the presence of C&D waste close to urban centers, rural roads, fields, forests, and ravines. According to the European Commission statistics, Spain leads the ranking of environmental offenses in Europe, with 1,513 known uncontrolled landfills throughout the territory. Furthermore, illegal dumping is the environmental offense most often recorded in Spanish police statistics (Ministerio del Interior, 2021). This phenomenon is more common in rural regions - due to the large size of geographical area to be monitored and the scarce human and financial resources available to environmental law enforcement agencies. This is indeed the case in Extremadura, a region in which different policies and approaches have been developed for preventing and managing this problem in the last few years. An example is the creation of PIREX (Integrated Waste Plan of Extremadura 2016-2022), and the cleaning and sealing of a large part of the landfills in the northern part of the region - with the collection of more than 80 000 tons of construction and demolition (C&D) waste.

Despite these efforts, the actual figure of illegal waste disposal sites in Spain is unknown. The police still do not identify or locate most illegal dumping points, although they need accurate information about these features for developing appropriate responses. Specifically, in terms of policing, there is an increasing reliance on geographically-informed policing, focused on identifying “hot spot” of crime and the development of problem-oriented approaches aimed at dealing with the spatio-temporal concentration of particular forms of crime (Braga, 2008; Braga & Weisburd, 2010; Goldstein, 1979). Indeed, in the existing literature there are many studies on waste using Geographic Information Systems (GIS). It is a valuable tool in environment research to identify and predict dumping sites, as well as to understand the complex spatial distribution pattern of illegal waste and the specific variables associated with its appearance, as well as to analyze smarter waste management alternatives (AlZaghrini *et al.*, 2019; Biluca *et al.*, 2020; Glanville & Chang, 2015; Hussen *et al.*, 2021; Jakiel *et al.*, 2019; Jordá-Borrell *et al.*, 2014; Paz *et al.*, 2018; Seeboonruang, 2016; Seror & Portnov, 2018; Vijay *et al.*, 2018). Geographic information systems and spatial analysis techniques are essential for studying criminal activity but the quality of the locational information about illegal dumping sites in Spanish police datasets is an unknown quantity. In addition, research on this issue is scarce and limited (Glanville & Chang, 2015; Jordá-Borrell *et al.*, 2014; Matsumoto & Takeuchi, 2011).

As noted by Ratcliffe (2004b): "Spatial crime analysis relies not only on accurate geocoding but also the achievement of a high level of geocoding success". There is some research about police geocoding for common forms of crime in urban settings, but we barely know anything about the georeferencing of illegal dumping sites. These crimes often occur at non-addressable locations and geocoding them is a challenge (Chainey & Ratcliffe, 2013). Criminologists and geographers have been primarily concerned with estimating a minimum hit rate for the process of geocoding (converting a textual description into a set of geographical coordinates) (Brimicombe *et al.*, 2007; Ratcliffe, 2004b), but some studies have also evaluated positional accuracy (Gerell, 2018; Hart & Zandbergen, 2012) and the impact of geographical error in subsequent analysis (Andresen *et al.*, 2020; Briz-Redón *et al.*, 2020; Harada & Shimada, 2006), whereas others have tried to estimate the impact of crime reporting bias on the geographical quality of police recorded crime data (Buil-Gil *et al.*, 2021). In this sense, the spatial or territorial component in a criminological study starts with a correct georeferencing or geocoding of the location of the crime (Mazeika & Summerton, 2017). Malpractice in police data collection can alter and bias analyzes of crime density (Ivert *et al.*, 2013), however, a greater reliability of the data is expected when the coordinates have been recorded at the crime scene using GPS devices than those extracted from addresses to be geocoded later (Gerell, 2018).

The purpose of this paper is to analyze the reliability of police data provided by the Nature Protection Service of the Civil Guard (known as SEPRONA) to locate solid spills in the rural region of Extremadura, as well as to propose good practices to the police to adapt GIS technology to environmental problems and needs for local planning.

2. Materials, data and methods

2.1. Geographical framework

This study was carried out in the Autonomous Region of Extremadura (SW Spain). Extremadura is an eminently rural region and a sparsely populated territory spread out across two provinces (Cáceres and Badajoz). This region covers 41 633 km^2, where just over 1 million inhabitants are distributed in 388 municipalities (Figure 1). Extremadura has a population density of 27 inhabitants km^{-2} and most of the population is concentrated in the major villages or towns (Nieto Masot & Cárdenas Alonso, 2017). The ten most populous villages concentrate 46 % of the population of Extremadura. This region is characterized by high aging rates, depopulation, high active population in the agrarian sector, and high unemployment.

There are two major factors that mark the territorial differences in Extremadura:

1) The two main communication axes: A-66 (known as Vía de la Plata) and A-5 (Madrid - Badajoz). The most populated villages in the region are located on these two communication routes: Plasencia, Cáceres, Mérida, Almendralejo and Zafra; and on the A-5: Navalmoral de la Mata, Mérida, Montijo and Badajoz.
2) Areas with a competitive agro-industrial sector located mainly in irrigated areas (e.g., Vegas del Guadiana and Valle del Alagón) and productive dry land such as Tierra de Barros.

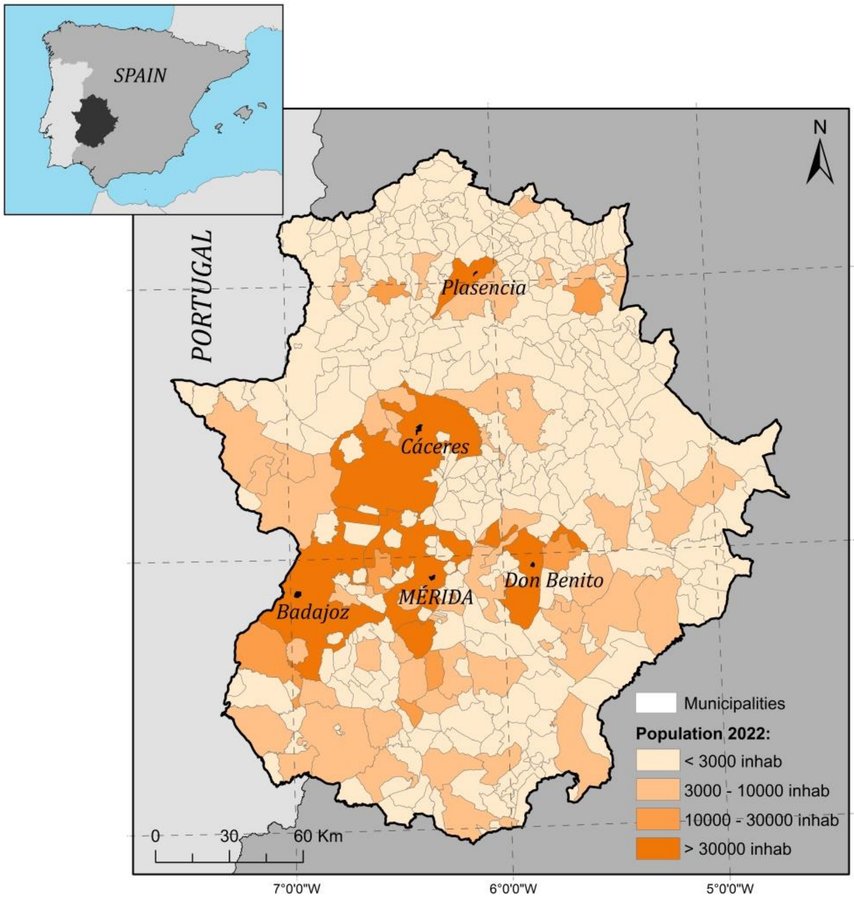

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Figure 1. Geographic location and distribution of the population (2022) of Extremadura.

2.2. Data source

Data are based on administrative complaints related to construction and demolition waste and where they took place in Extremadura in 2018 as recorded by the Spanish police. The Nature Protection Service of the Civil Guard (known as SEPRONA) provided us with a vector file (.shp) with a total of 1238 geolocations about illegal dumping directly collected at the crime scene using a GPS device. The distribution of the points was performed using QGIS software. The instrumentation and coordinate reference system used for waste monitoring in the provided data are unknown.

The vector layer contained the following information:

a) Id
b) Year
c) Criminal scope
d) Criminal type
e) Municipality
f) Province
g) Country

The layer of points has the reference system UTM 29N with datum World Geodetic System 1984 (WGS84).

The Civil Guard data does not include the reported date and time of the monitoring. Only the year has been taken and not the hour or the day. Another data source is up-to-date orthophotographs of the Spanish Geographic National Institute (CNIG, 2019) as visualized by web map service (WMS) through QGIS. The orthophotographs have a spatial resolution of 0.25 m with a European Terrestrial Reference System 1989 (ETRS 1989) coordinate reference system.

2.3. Methodological approach: photo-interpretation and field survey

A detailed verification of construction and demolition waste was conducted through the orthophotographs provided by the WMS. Georeferenced data was tagged based on three types (Figure 2):

1) *Yes*: there is construction and demolition waste where the administrative complaint is located.
2) *Probably*: there is no illegal dumping where the administrative complaint is located, but there is rubble very close to the geolocation.
3) *No*: there is no residue where the administrative complaint is located (for example, the geolocation is on a roof)

All this information was exported to new Excel files (.xls) to work with them as a database, by adding new attributes, such as (1) the real distance between the location of the complaint and the illegal dumping (in the case of the data defined as "probably") and (2) the type of land use where the complaint was located in those defined as "No".

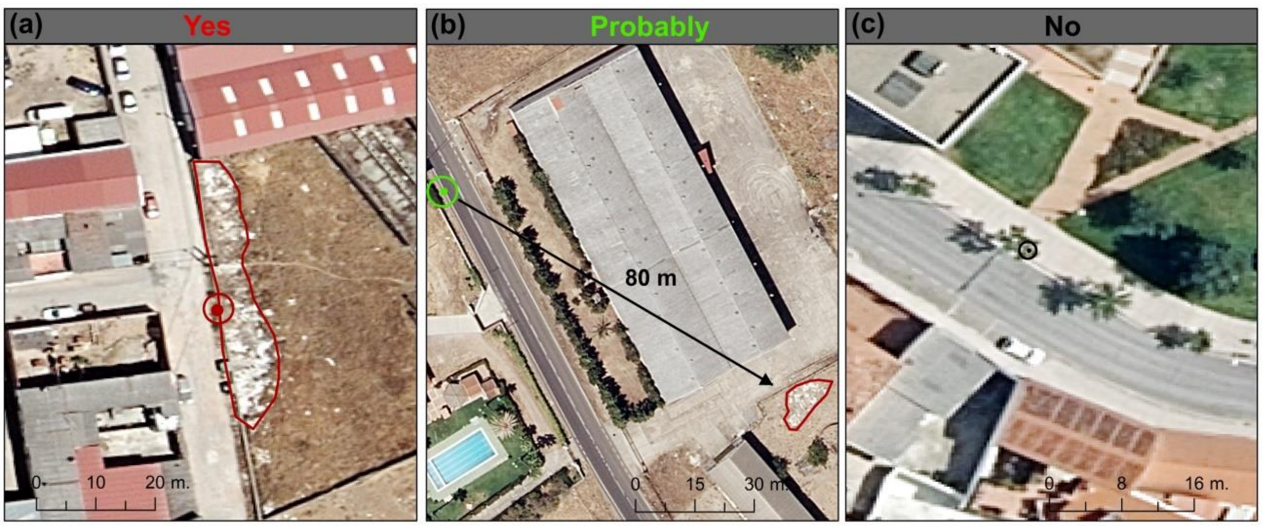

Figure 2. Illustrative examples of the methodological approach with orthophotographs from 2019 in the background are shown: (a) really exist illegal dumping in the location of the complaint, (b) the complaint is not exactly located in construction and demolition waste and (c) there is no illegal dumping.

The checking for presence of rubble was also carried out through field survey (Figure 3). A total of 58 locations were randomly checked in situ for the existence or not of illegal dumping. Mainly the field survey was conducted in Mérida, Cáceres, Badajoz and Don Benito because these cities are the four most populated in Extremadura and located among the top 10 with the highest concentration of complaints. In addition, the non-presence of chemicals was verified in the 58 sites visited.

Figure 3. Field observations showing construction and demolition waste in two different locations: (a) in a developable land in Cáceres city and (b) in the field next to an unpaved road in the municipality of Mérida.

Finally, to better understand the results obtained, we applied a qualitative methodology based on interviews with the Civil Guard agents who provided the information.

3. Results and discussion

The main results obtained in the analysis are presented below. Of the 1 238 administrative complaints, 725 were complaints with different geolocations, which represent 59 % of the total. In many cases (n=513) more than one complaint matched the same location, and in these cases a single location for each complaint was chosen. This means that a single geocoded site can yield multiple police reports or records. It is common for a single crime to lead to the initiation of more than one procedure, mainly because more than one complaint has been filed, or for any other reason that generates this situation (Serrano Gómez, 2011). Weisburd (2015) defines this scenario as the law of crime concentration at place, which states that for a defined measure of crime at a specific microgeographic unit, the concentration of crime will take place within a spatial range for a cumulative proportion of crime.

The municipalities with at least one administrative complaint for construction and demolition waste represent 61 %. Although the spatial distribution of the complaints in the region is heterogeneous, the complaints were mainly concentrated around the most populated towns (Cáceres, Badajoz, Mérida and Don Benito) and close to the main communication routes (Figure 4a).

However, almost 90 % of the reports provided by SEPRONA were not related to observed rubble (Figure 4b). Only 2 % were clearly located in spaces where construction and demolition waste could be observed, and 9 % of the complaint is not exactly located in places where waste can be observed, but this kind of rubble is observed in close proximity to the geolocation recorded in police data. By province, 12 complaints were correctly geolocated about illegal waste in Cáceres and only 4 in Badajoz. However, 24 complaints were not exactly located about illegal waste in Cáceres and 42 in Badajoz, but there was waste very close to the geolocation (Figure 4c). According to Matsumoto and Takeuchi (2011) and Lucendo-Monedero *et al.* (2015), one of the main problems in the study of illegal dumping, using official statistics, is the lack of consistent and reliable data about the location of dumping sites and our analysis suggest this seems to be the case when using Spanish police data.

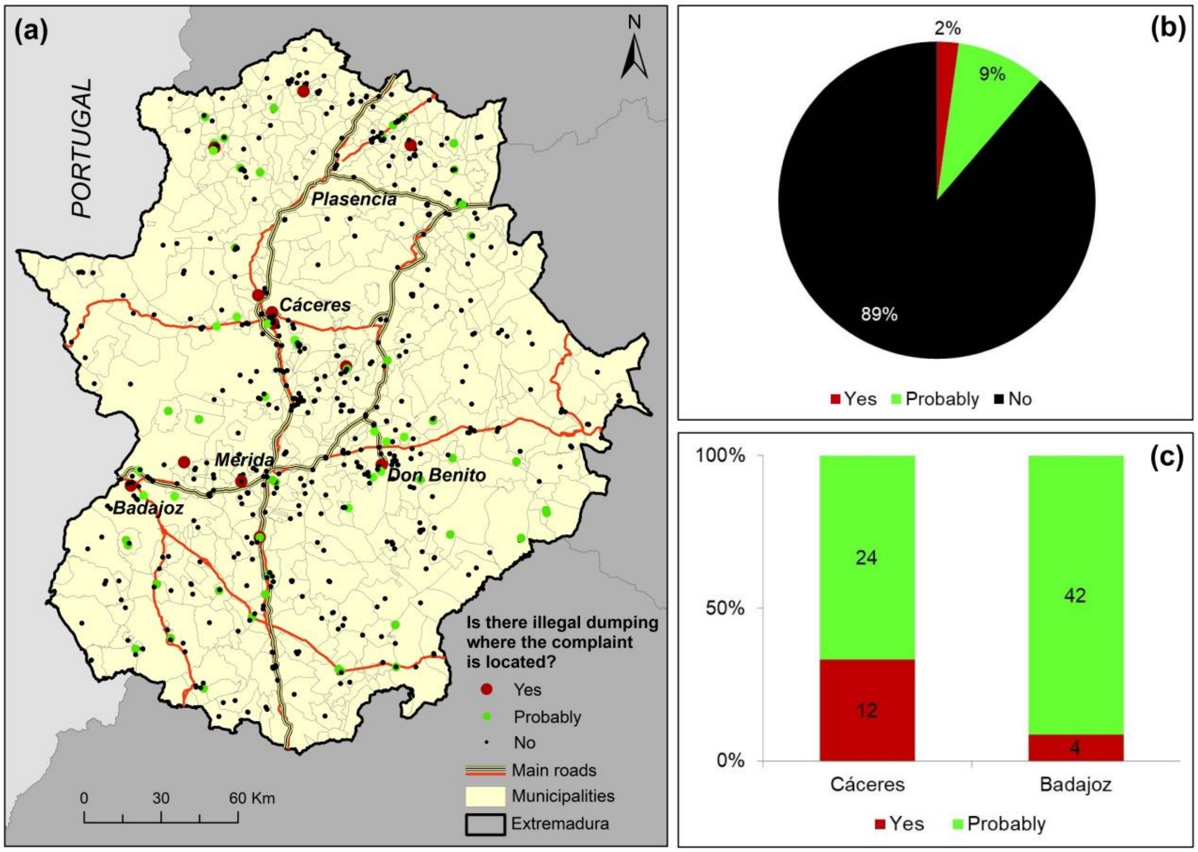

Figure 4. (a) Spatial distribution of administrative complaints for illegal dumping in Extremadura depending on the existence or not of waste where the complaint is located, (a) percentage of administrative complaints depending on whether or not they were located on construction and demolition waste, and (b) number of administrative complaints consistent with waste by provinces.

By municipalities, Cáceres and Badajoz registered a large number of administrative complaints with 43 and 24, respectively (Figure 5a). Don Benito is the municipality with the largest number of correctly geolocated complaints regarding waste, representing 45 % of the complaints. On the contrary, Cáceres and Badajoz were the municipalities with the lowest number of correctly geolocated complaints, with 25 % and 19 %, respectively. Figure 5b presents the relationship between the number of administrative complaints and population by municipalities which were significantly correlated using a second-degree polynomial functions.

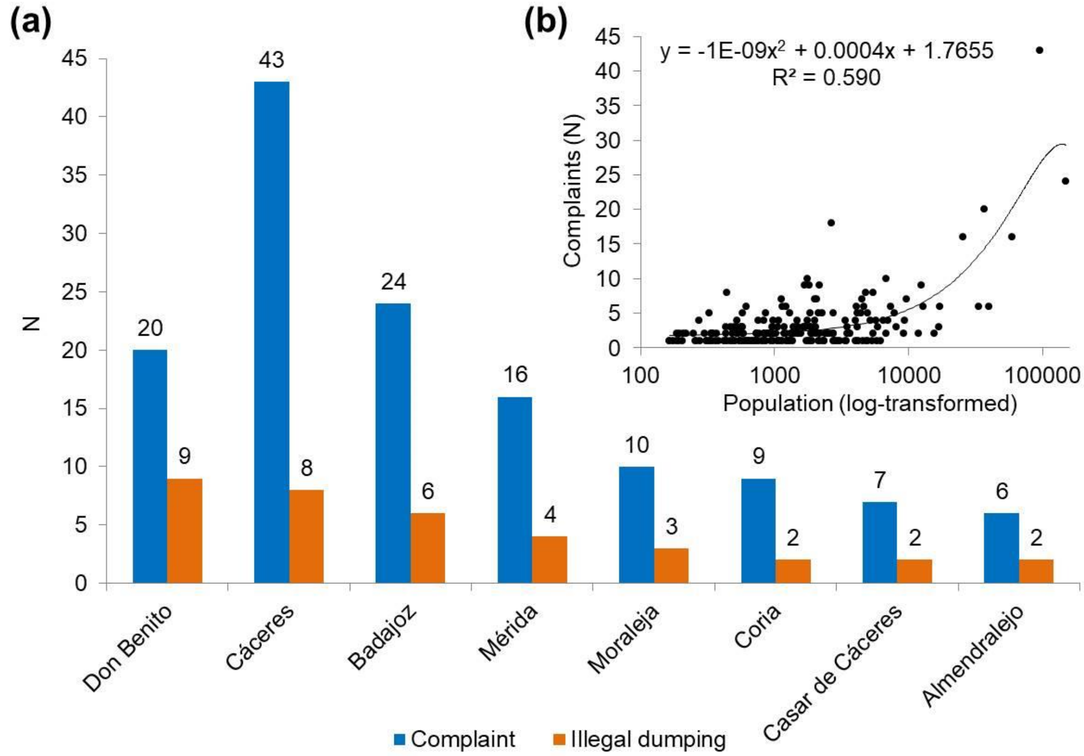

Figure 5. (a) Municipalities with the largest number of administrative complaints and illegal dumping and (b) relationship between the number of administrative complaints and population (log-transformed) by municipalities.

To further elaborate the analysis, the distribution of error was considered. The difference in distances between the location of administrative complaint and the illegal dumping for data classified as "probably" are shown in Figure 6. The mean and median distance was 64 m and 48 m, respectively. 54 % of the complaints classified as "probably" display a distance to the waste of less than 50 m. A reasonable hypothesis would be that the distance less than 50 m presumably represents geocoded locations by means of inaccurate monitoring. The mean distance between two different locations by Ratcliffe (2001) was lower than those presented in this study with a separation of 47 m on average. On the contrary, Gerell (2018) found a mean distance of 83 m, i.e., a distance larger than the estimated in this study.

The larger distances are likely to be associated with locations for which it has not been possible to determine the exact location of the waste because the exact place of the crime is unknown (Newton *et al.*, 2014), sometimes resulting in rough georeferencing (see Figure 2b, geocoding in the center of a road), also due to places where access is not allowed, or simply miscoded data. Two potential example of where there is no waste at the location of the complaint could be if the complaint is registered with the police station and not at the exact location of the demolition waste or if a SEPRONA member in charge of logging the location with a GPS device did so from the comfort of his means of transport rather than from the exact location of the rubble. As noted by Gerell (2018), unreliable geographic locations can lead to mislocations of an entire area with an even greater impact on the effectiveness of police operations.

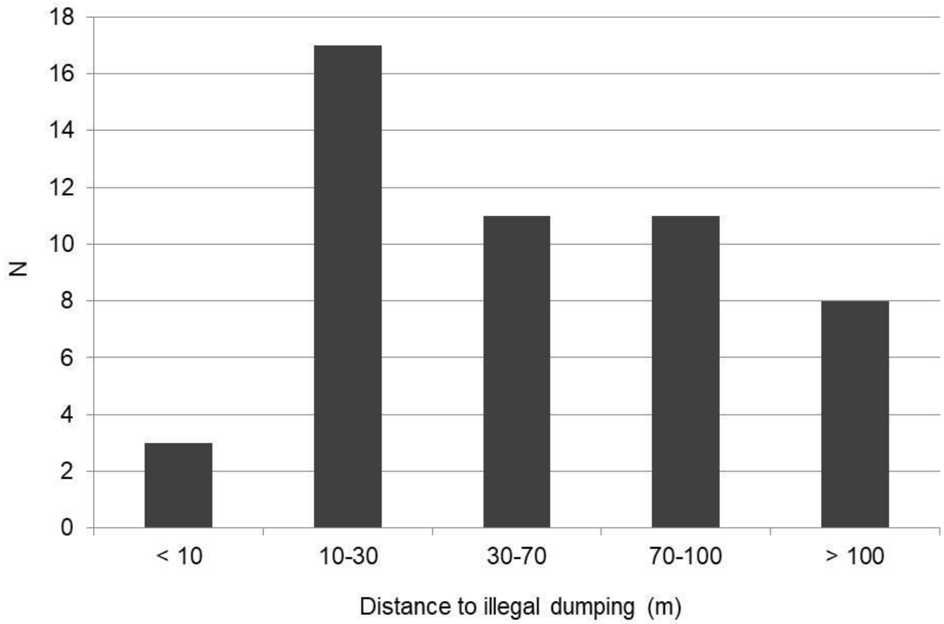

Figure 6. Distribution of distances between the location of administrative complaint and the illegal dumping.

Table 1 displays the location of complaints where there was no construction and demolition waste. Our study revealed that 40 % of the complaints that were not located in waste (i.e., those labeled as "no") were located in urban land, highlighting the complaints located on streets and roofs with 69 % and 27 %, respectively. In the scientific literature there are no studies on the evaluation of measurement error to identify solid waste dumping sites that allow these results to be compared. Nevertheless, there are several studies on probability areas of presence of illegal dumping that help to understand this distribution of "no" type complaints. For example, Jordá-Borrell *et al.* (2014) identified, by means of geo-statistical modeling tools, some factors related to the presence of illegal dumping sites in the Andalusian region of Spain. This study highlighted that a large percentage of the sites were found in urban areas and in the most populated villages (upper than 10 000 inhabitants). Our study revealed that 38 % of the "no" type complaints were located on rural and natural land, mainly in the countryside and forest areas. These findings are in line with the results of several other studies, which revealed the presence of illegal dumping in forested areas (Seror & Portnov, 2018; Silvestri & Omri, 2008). This group of complaints (i.e., type "no") was also located on roads and developable land, representing 15 % and 7 % respectively. Matos *et al.* (2012) and Jordá-Borrell *et al.* (2014) found that most illegal dumping sites are located near roads. Moreover, C&D waste can be used as a filling material in unpaved roads (Seror & Portnov, 2018). These results are visualized with some examples in Figure 7.

However, the non-presence of waste where complaints were registered and the geolocation of waste on urban elements (e.g., roofs) may be for various reasons:

1) Probably, part of the C&D waste sites located in public areas (e.g., roads, urban and periurban areas) has been able to be removed by local management systems between 2018 and July 2019. The orthophotographs of the Spanish Geographic National Institute were obtained in July 2019 while the administrative complaints of the SEPRONA were recorded throughout 2018.

2) The geolocated administrative complaints about rooftops and reservoirs, for instance, are probably attributed to an inaccurate georeferencing or geocoding of the C&D waste.

3) Finally, the administrative complaints located in the middle of the countryside and without the presence of C&D waste may be because the exact place is in doubt and it is attributed to more general places (Gerell, 2018).

Table 1. Location of administrative complaints where there is no construction and demolition waste.

TYPE	N	%	SUBTYPE	N	%
Urban land	257	40 %	Street	177	69 %
			Roof	70	27 %
			Industrial area	4	2 %
			Main square	4	2 %
			Park	1	0 %
			Parking space	1	0 %
Developable land	43	7 %			
Rural land	248	38 %	Countryside	244	98 %
			Reservoir	2	1 %
			Agricultural area	2	1 %
Communication routes	94	15 %	Unpaved road	34	36 %
			Road	54	58 %
			Roundabout	6	6 %

Type/subtype = typology of land uses. N = number of cases. % = percentage of cases belonging to a type of land use.

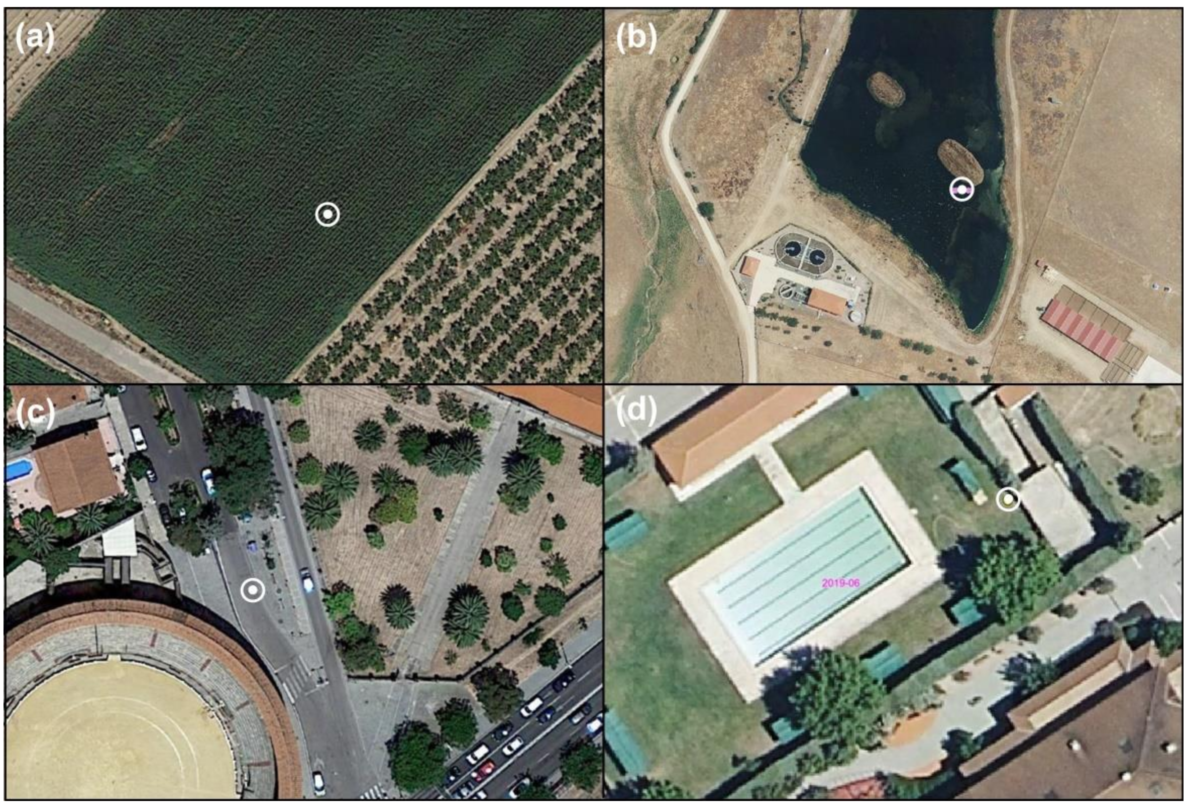

Figure 7. Orthophotographs observations showing places where complaints (white points) were located without illegal dumping. Here are some examples of locations: (a) countryside, (b) reservoir, (c) road and (d) private plot.

Considering the high number of areas where no rubble could be observed, it seemed unlikely to us that all the C&D waste points were not there because, at some point between 2018 and 2019, they had been cleared. To better understand the absence of waste in the coordinates provided, we show the results obtained with the agents of the Civil Guard in order to find answers. They were not surprised at the results. For them, the reason for the apparent volume of error is due to officers´ approach to coding the information. The georeferenced coordinates are collected as one more field to be filled in a computer application, but not (at present) for the purpose of statistical exploitation or police intelligence. As noted by Chainey and Ratcliffe (2013): "whilst it is important to ensure that the geocoded crime data are of good quality, it is also important that in the search for data perfection, the level of data quality that is required of crime data is proportionate to the purposes to which it will be applied". Nor is training given to agents on how to geo-position infractions, nor are there protocols in this regard, nor internal accountability measures. This would probably be the cause of the poor quality of the data. For example, field agents are unaware that they must remain at the location of the offense for a certain time before saving the coordinate, since it takes time for the GPS to properly square their position. This could explain, for example, why there is a gap in the distance between the real point and the georeferenced one in some instances, since the signal centers the position of the agent when he is leaving the place (e.g., Figure 2b). Other times it is simply due to intentional bad practice by agents. Gerell (2018) noted that one possible source of error would be the location with a GPS device from a comfort place for the agent (inside of a car) rather than from the exact location of the incident. In our study, this fact is exemplified in coordinates that coincide with bars or police stations.

Aside from a malpractice in data collection by agents, another possible source of error is the use of georeferenced data collection methods with large measurement errors. For that reason, the use of a receiver enabled by The European Geostationary Navigation Overlay Service (EGNOS), which is the first European satellite navigation system, is suggested. An EGNOS-enabled receiver provides location accuracy to within 3 meters. Without EGNOS, a standard GPS receiver (e.g., mobile phone or smart watches) only provides accuracy to 17 meters. In addition, another important issue is that each agent has georeferenced the offense using different devices (a mobile phone, a smart watch, etc.) inducing additional bias. Criminological studies including the spatial component, by means of GIS, requires that the geocoded data be 100 % accurate, precise to the exact location of where the crime took place, have been registered correctly, bare complete and can be trusted (Chainey & Ratcliffe, 2013). In this sense, it seems that the lack of a GIS-oriented police culture in Spain may perhaps explain the little importance given to these practices and protocols (Wang, 2012).

4. Conclusions

Construction and demolition waste is part of the urban and rural landscape of Spain, its location and prevention being a challenge for researchers and security forces. In this article we examine 1 238 geo-referenced administrative infractions by the Civil Guard in the rural region of Extremadura using a case-by-case review methodology to check if, in fact, debris existed in the coordinates provided by the police. We found that only in 2 % of the infractions the presence of debris in a georeferenced place was confirmed and that, in 9 % of the cases, its presence was probable when the debris was located at a distance of less than 100 meters. The most relevant finding is that in 89 % of the cases there was no residue in the reported place. In these cases, the coordinates placed them on streets and rooftops (in urban areas) and in countryside and forest areas (in natural areas) because the lack of positional accuracy in police data is a common finding (Brimicombe *et al.*, 2007; Ratcliffe, 2004a). In fact, we had anticipated a better quality of the data because it was collected directly by the agents using GPS devices rather than having to go through the process of geocoding from a textual address. To seek explanations for these findings, the quantitative data was complemented with interviews with key SEPRONA officials. They believe the data was not reliable for locating residues because it has not been properly collected. This is fundamentally due to three reasons: there is no police culture to take advantage of GIS data and then exploit it for tactical and strategic analysis, that is, it is not a priority issue; that field agents do not handle accurate and adequate techniques for georeferenced data collection and that they do not have the training and protocols to properly geo-position the infractions.

The implications of this research are multiple. First, it enriches the field of criminological studies about data quality of police to geocoding and georeferencing crimes collected by GPS devices in illegal dumping crimes. Second, the fact of not having reliable official data to locate waste makes it difficult to: know its incidence and the characteristics of the phenomenon, its association to different variables, patterns, etc.; predicting vulnerable areas; developing other methodologies for locating spills that require a "ground truth", for example in remote sensing techniques; and that the police can better manage their own resources to carry out better crime prevention. Third, this implies looking for alternative data sources for contrasting the information provided as a way to achieve a better geographic reliability (Gerell, 2018). In the Spanish context this would only be possible by developing field work to verify that the complaints GPS points are correct; creating web-based platforms involving citizens in locating dumping sites; or developing a remote sensing procedure capable of automatically recognizing dumping sites using deep learning.

Fourth, using reliable GIS data would be very suitable in rural and sparsely populated areas, such as Extremadura, as police resources are scarce and more effort is needed to prevent crime. Five, it is very important to make the police aware of the quality of the data they generate and the benefits they can obtain from it. According to (Ratcliffe, 2004b), practitioners and academics in the fields of crime analysis have been quick to realize the training requirements and have been gearing their respective organizations to carry out, firstly, a correct data collection and later a complete spatial analysis of the crime. In this regard, we consider that good training for field agents, the development of information collection protocols, as well as the development of a good practice guide can be key to ameliorate this problem.

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